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TU4C-3

Waveguide Multimode Directional Coupler for Harvesting Harmonic Power from the Output of Traveling-Wave Tube Amplifiers

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Outline

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- Benefits & Challenges
- Waveguide Multimode Directional Coupler
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  - –Coupler Fabrication
  - –Coupler Characterization
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- Acknowledgement

Introduction – Motivation

- Growing user community
  - Congestion in the traditional Ku, K, and Ka frequency bands designated for space-to-ground data communications
- Next available bands above Ka-band are the Q-band (37-42 GHz) and E-band (71-76 GHz)

Benefits of Migrating to Higher Frequencies

- Allocated bandwidth at Q-band & E-band is in excess of 4 GHz, which can enhance throughput by 10X or higher
  - Competitive with terrestrial fiber optic & wireless service in terms of cost per transmitted bit
- Narrower beam width & smaller spot size
- Greater frequency reuse & spectral efficiency

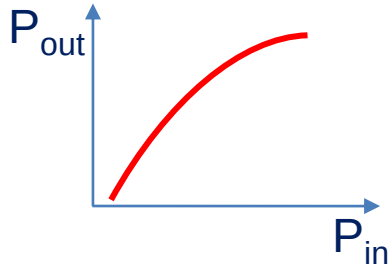
Challenges

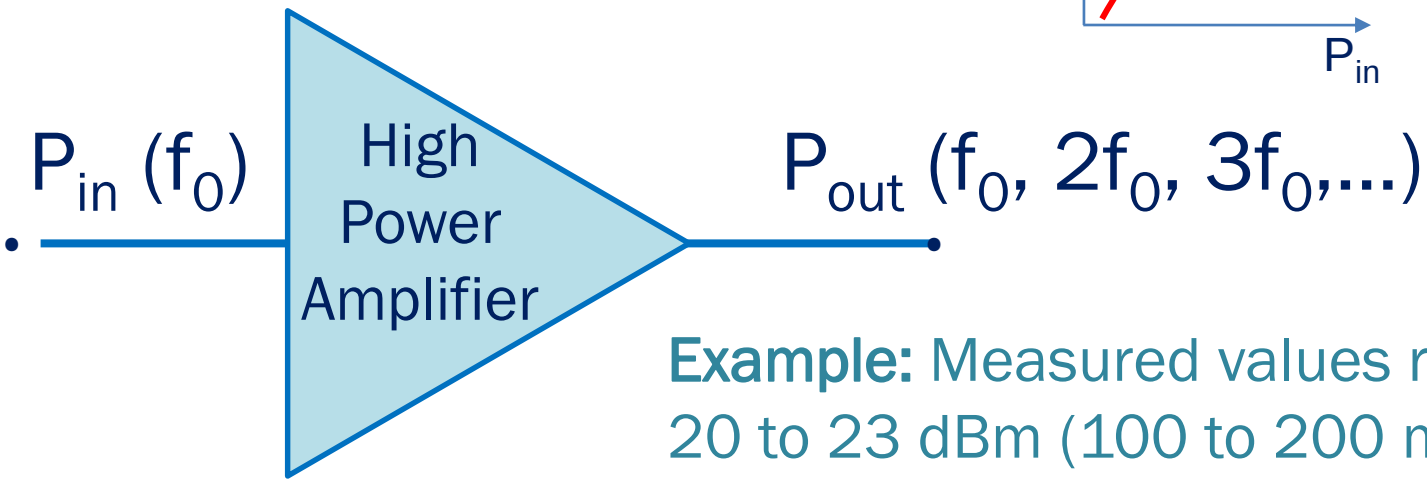
- Lack of rigorous studies to understand atmospheric effects on radio wave propagation at Q-band & E-band
  - These studies are essential for the design of a robust system for deployment in space

Challenges
(continued)

- A wide band beacon transmitter has to be deployed on a satellite
  - Ground receivers have to be dispersed over climate zones of interest
  - Statistical data on rain attenuation, fading, change in refractive index, scintillation, de-polarization effects, etc., have to be acquired for a period of 3 to 5 years

High Power Amplifier Harmonics

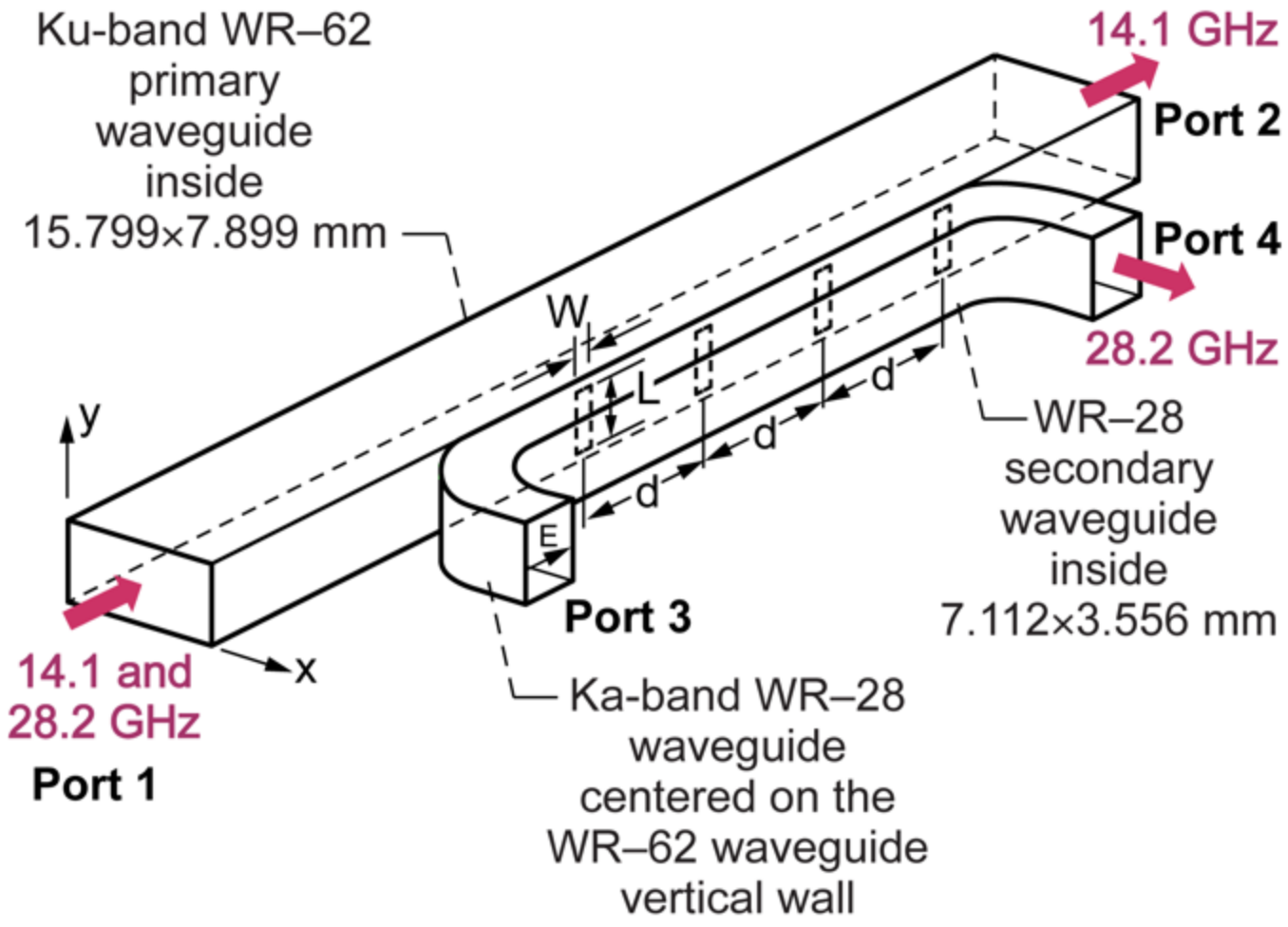




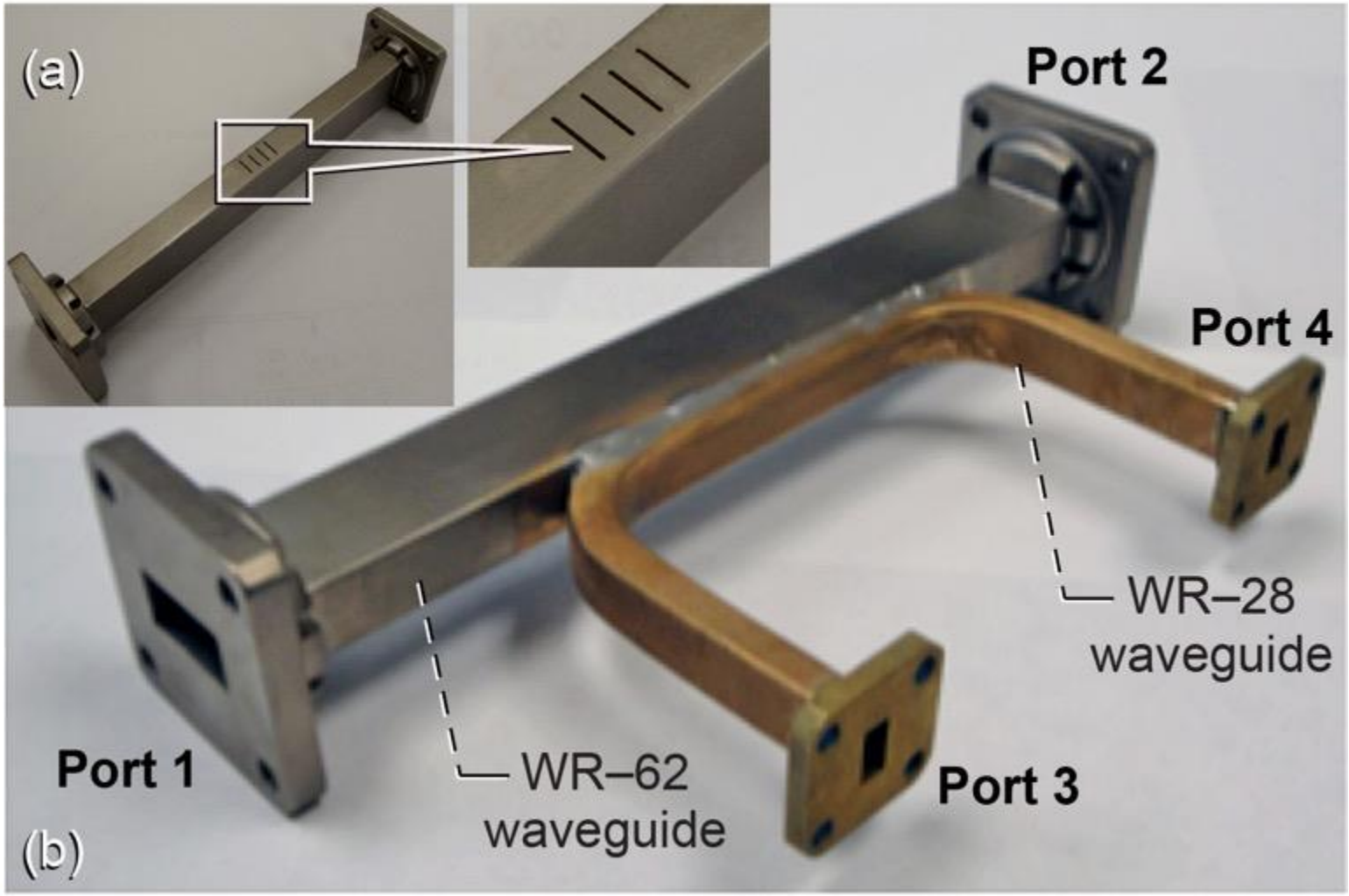
Example: Measured values range from 20 to 23 dBm (100 to 200 mW) for the 40 W K-band TWTA

TWTAs on board satellites for data transmission operate with constant envelope type waveform (for e.g. QPSK) and at saturation for peak efficiency

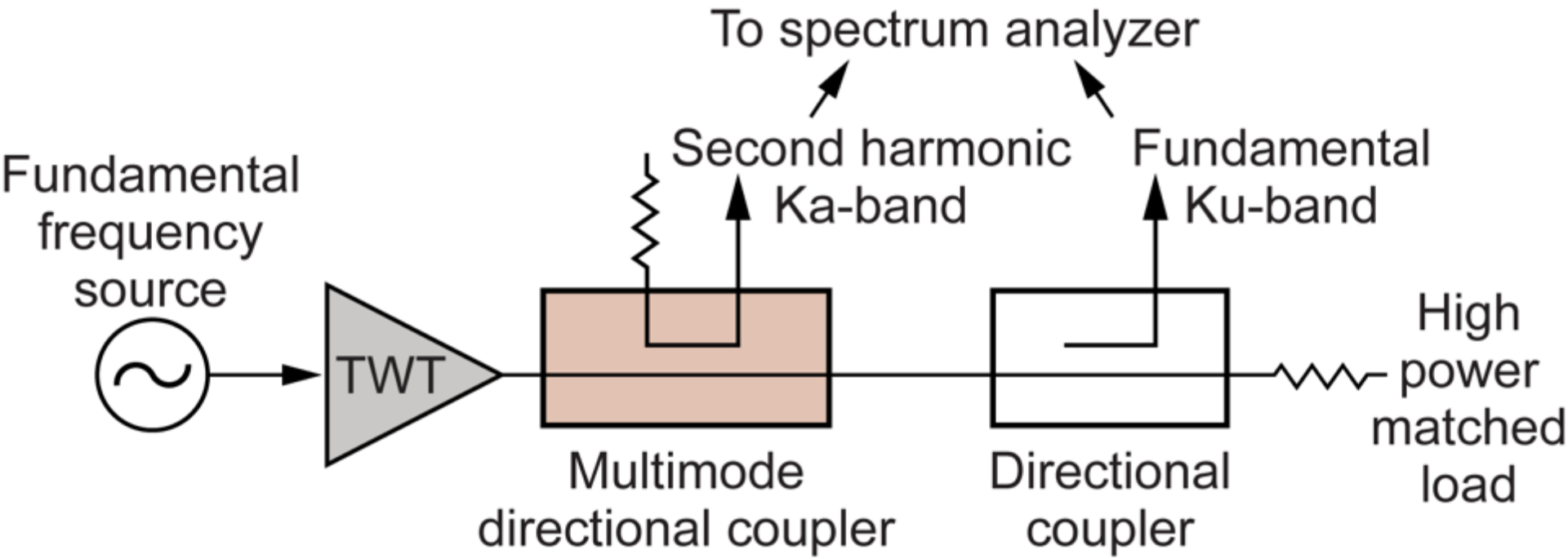
Waveguide Multimode Directional Coupler (MDC)



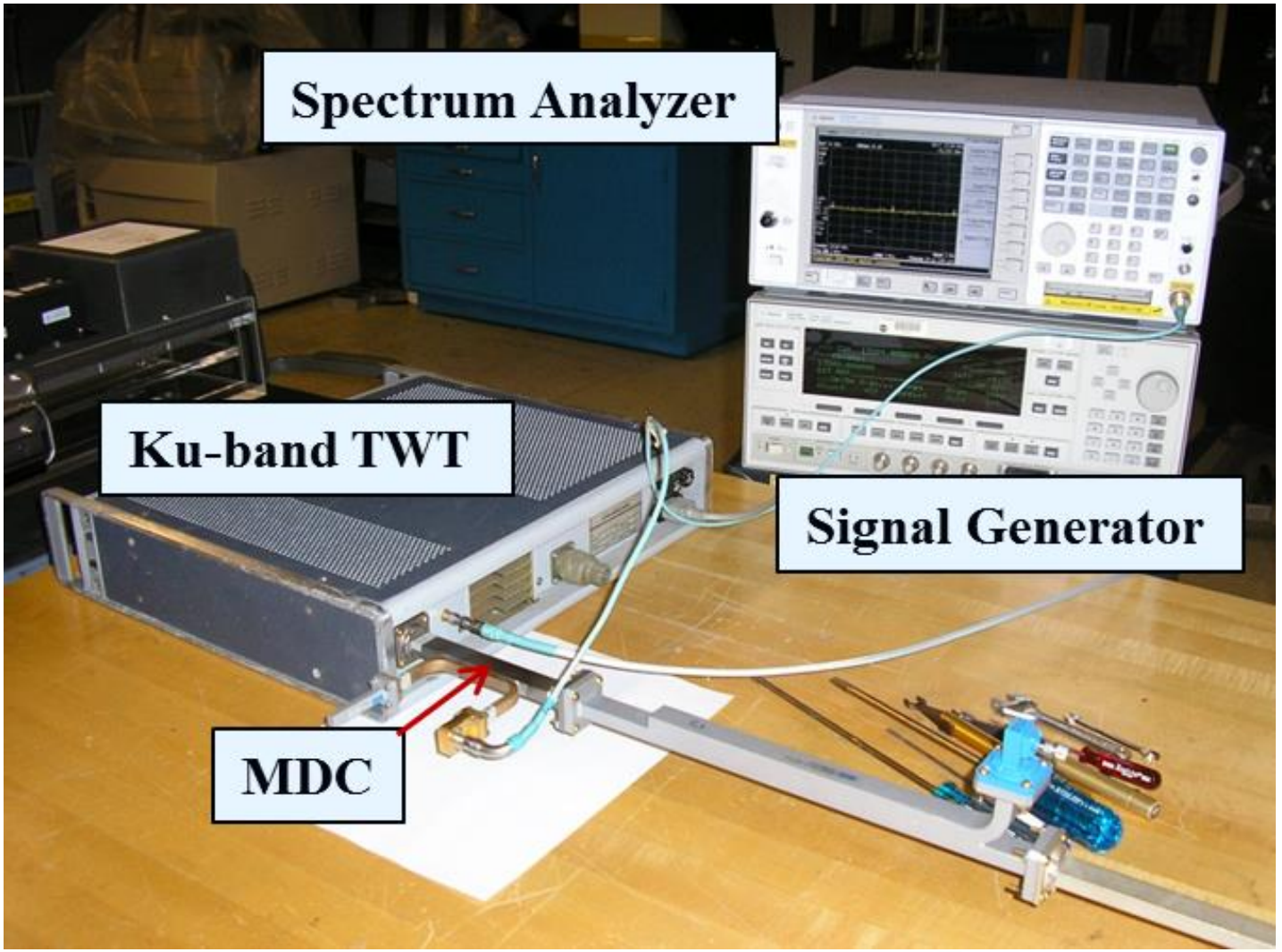
Fabricated Ku-Band/Ka-Band Waveguide MDC



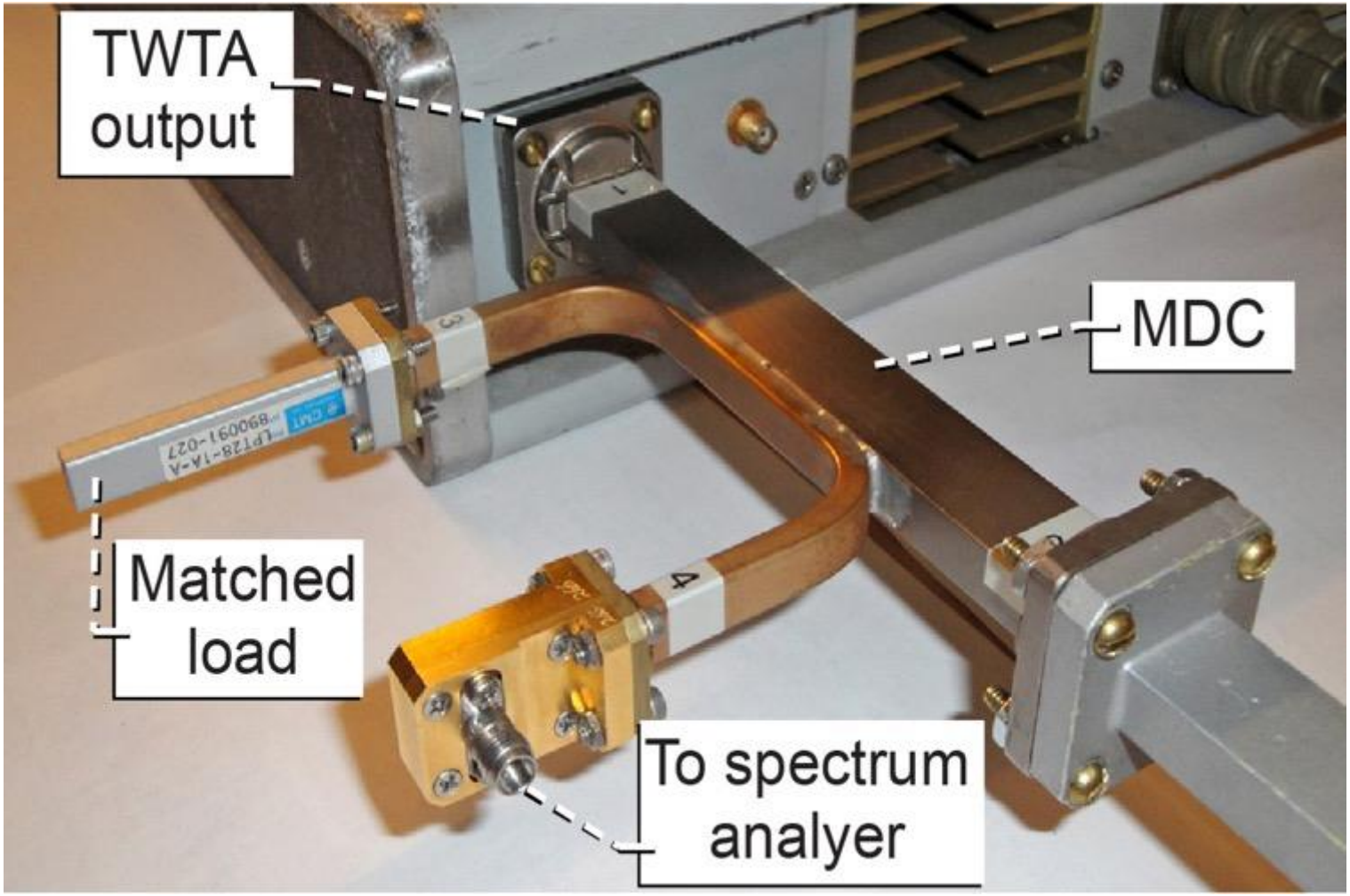
Test Circuit for Measurement of Power at Fundamental (f_0) & Second Harmonic ($2f_0$)



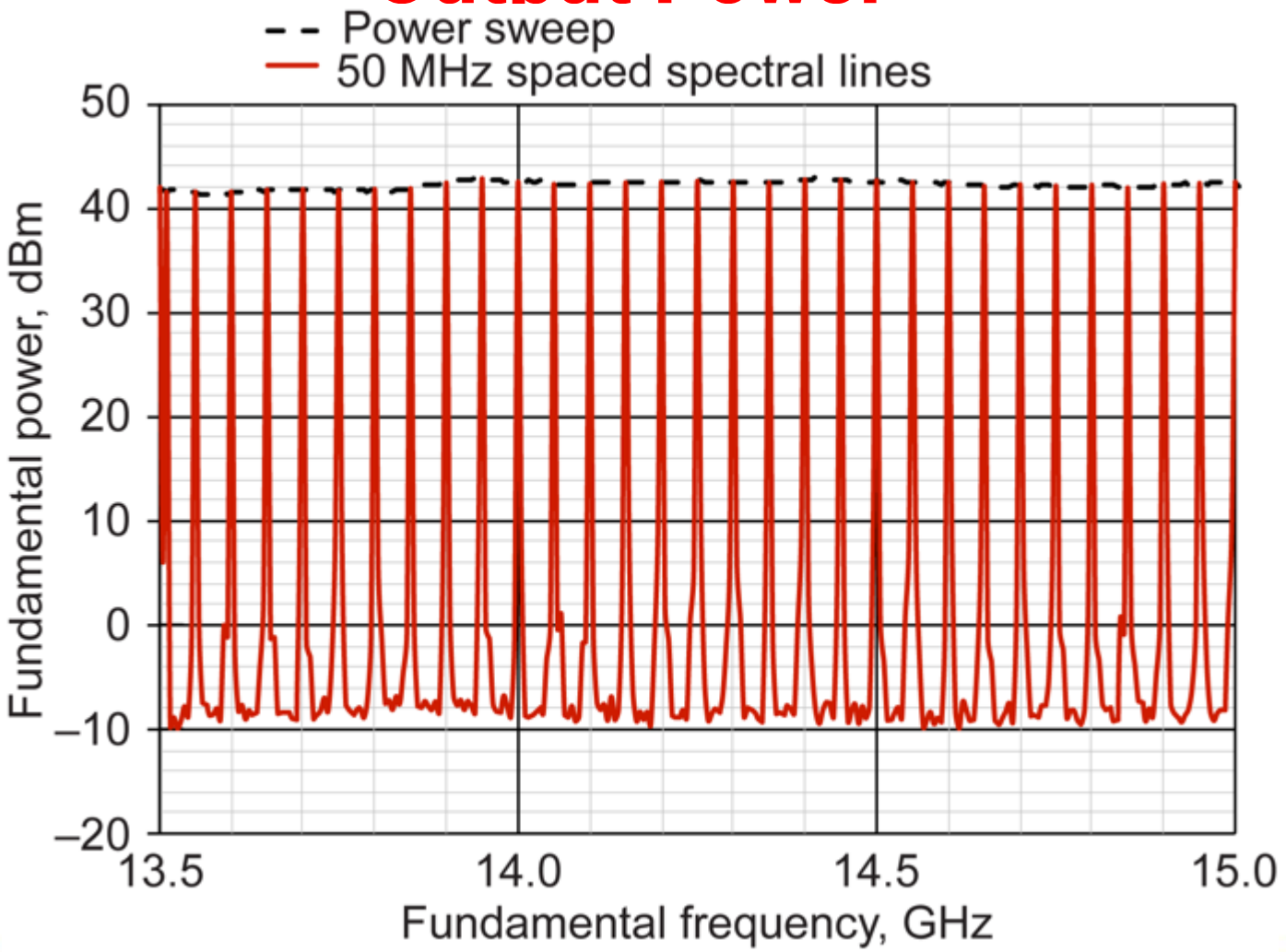
Experimental Setup - Ku-Band/Ka-Band MDC Tests



MDC at Output Port of Ku-Band TWTA

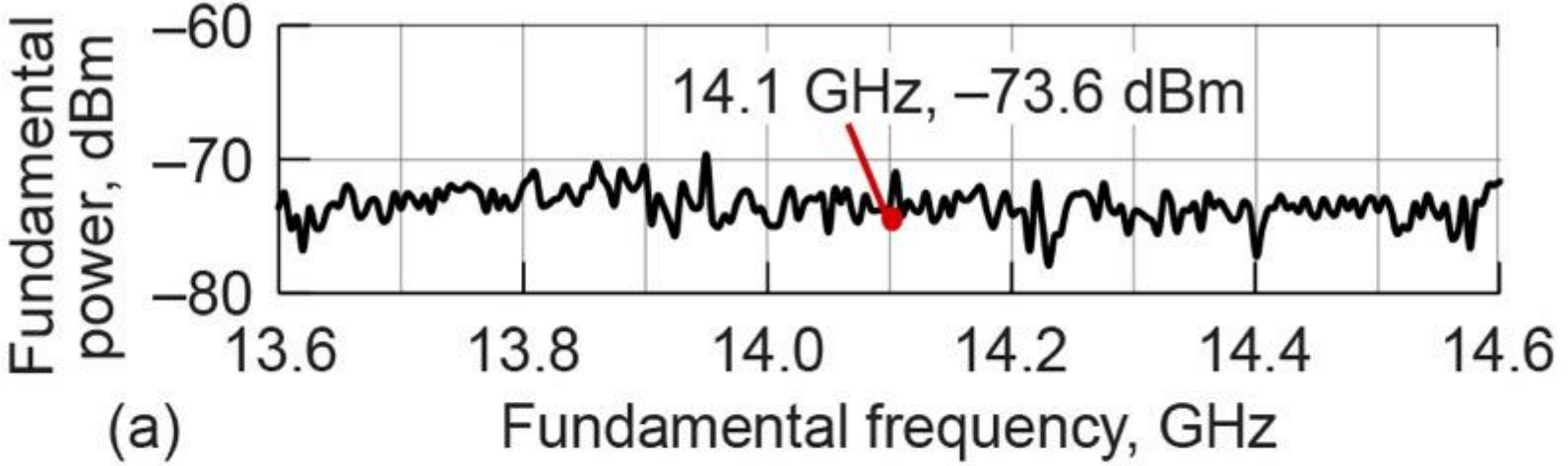


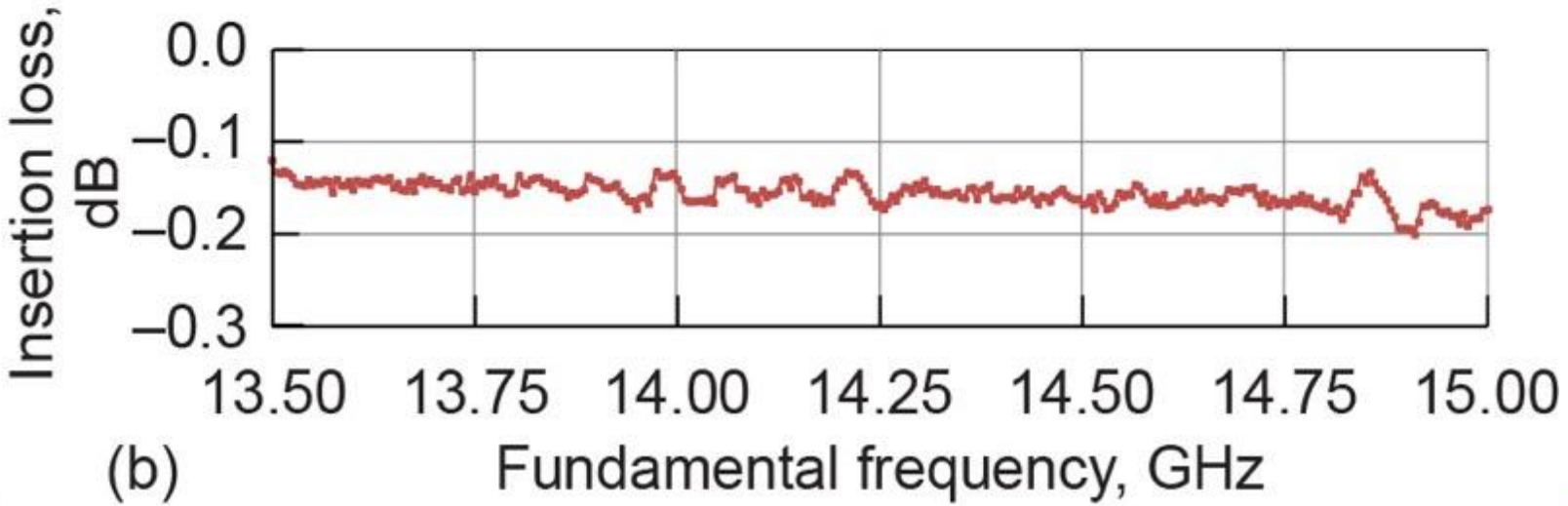
Measured TWT Fundamental (f_0) Saturated Output Power



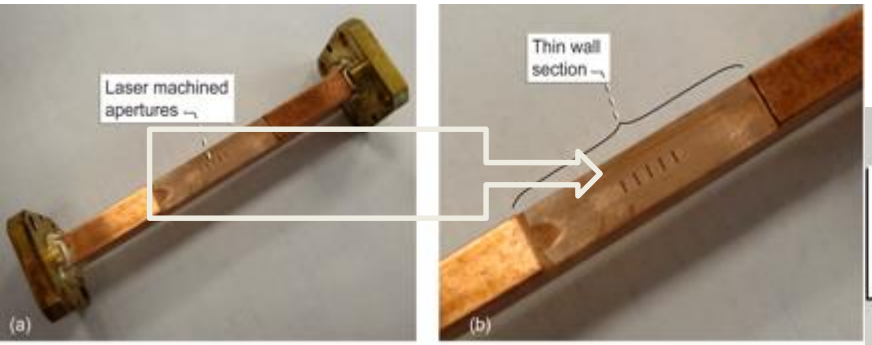
Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC

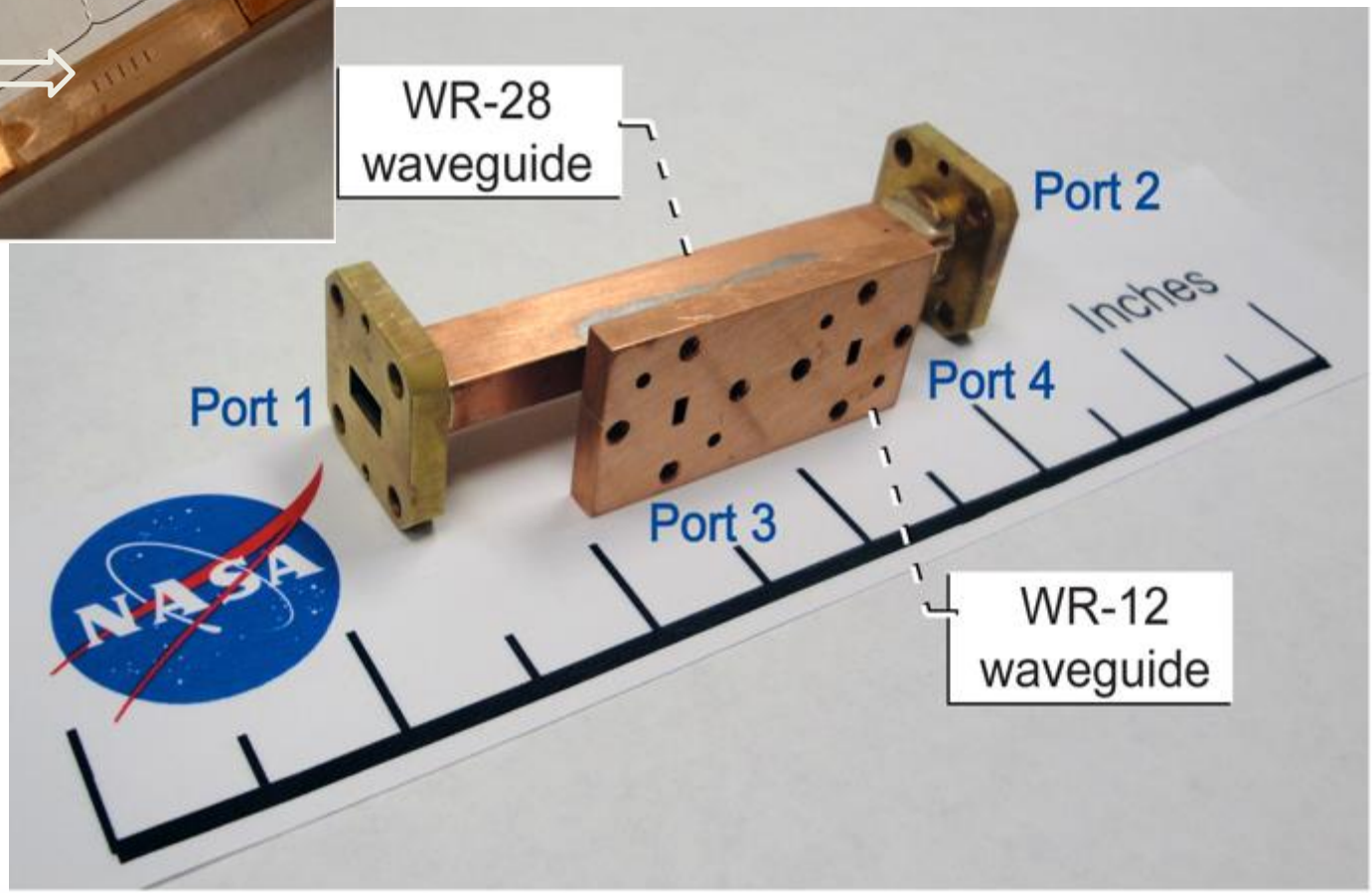
Measured f_0 Power at the MDC Port 4 & Measured Insertion Loss Between Port 1 & Port 2



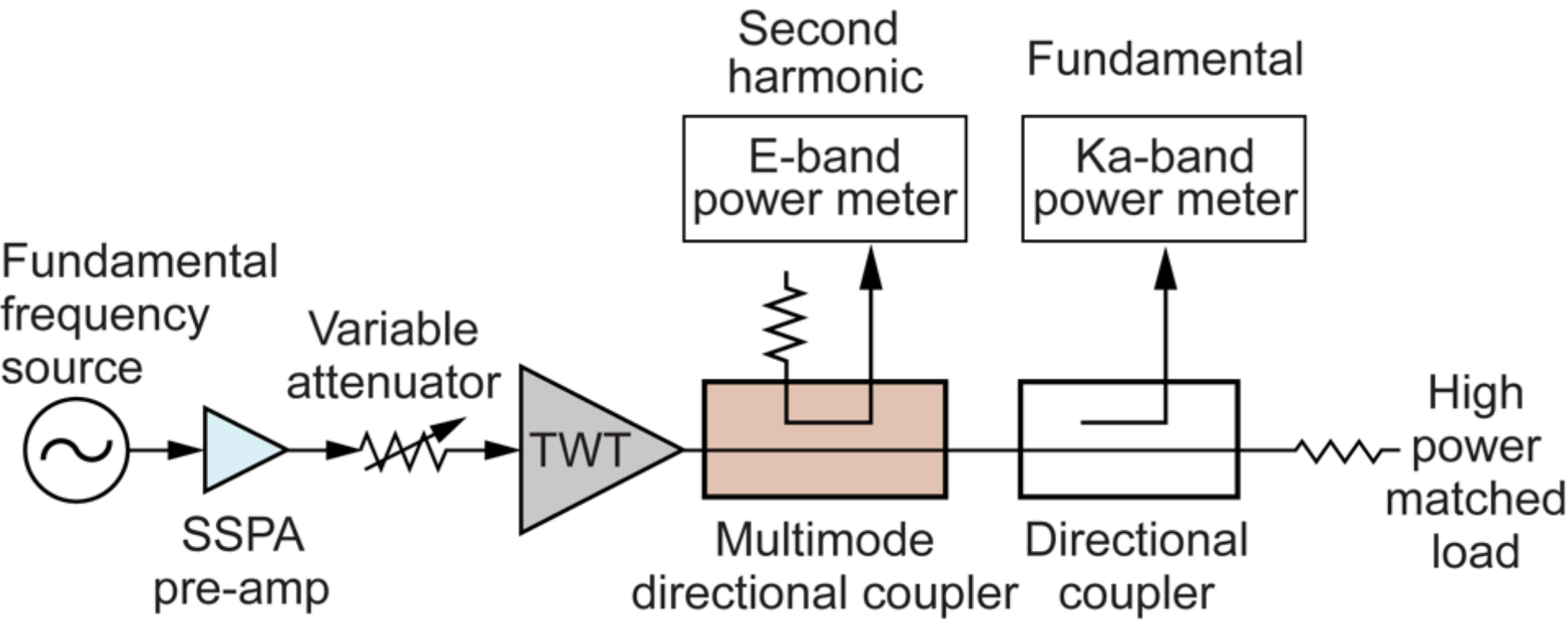


Fabricated Ka-Band/E-Band Waveguide MDC

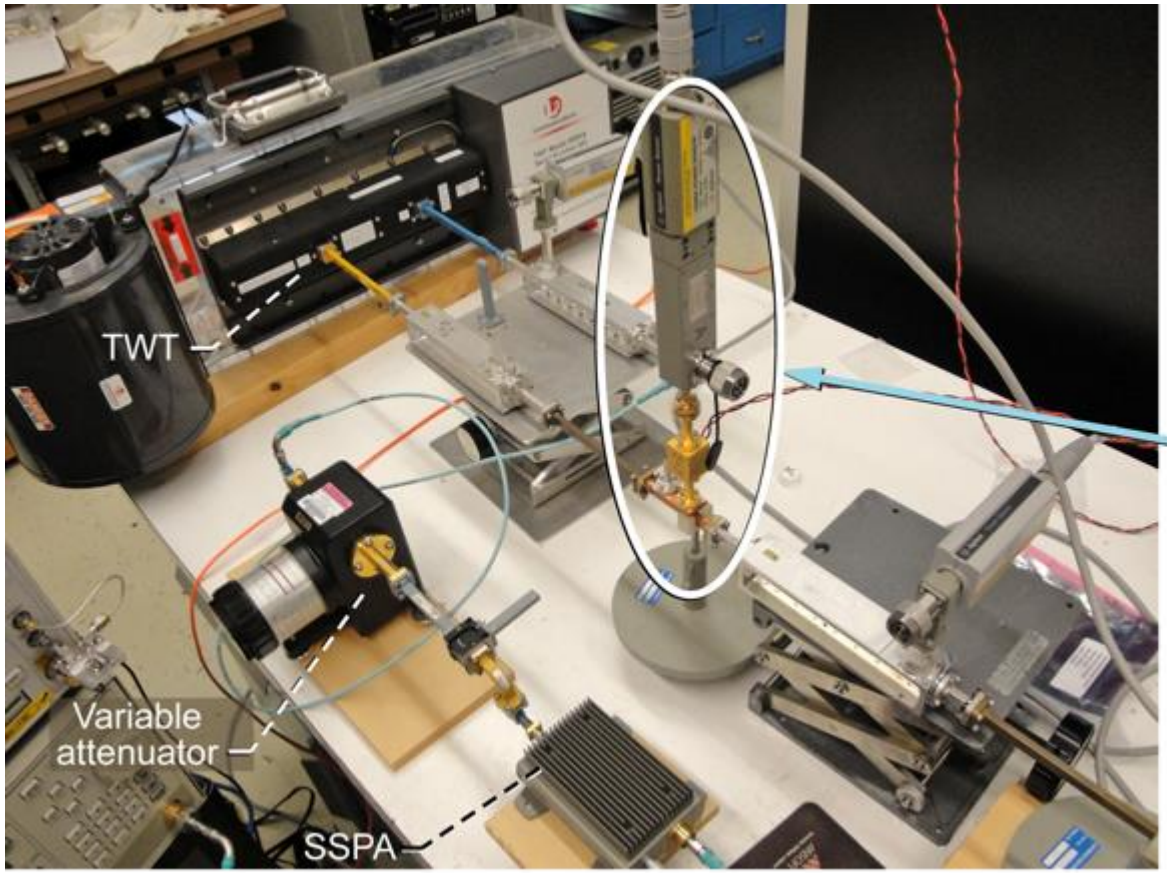


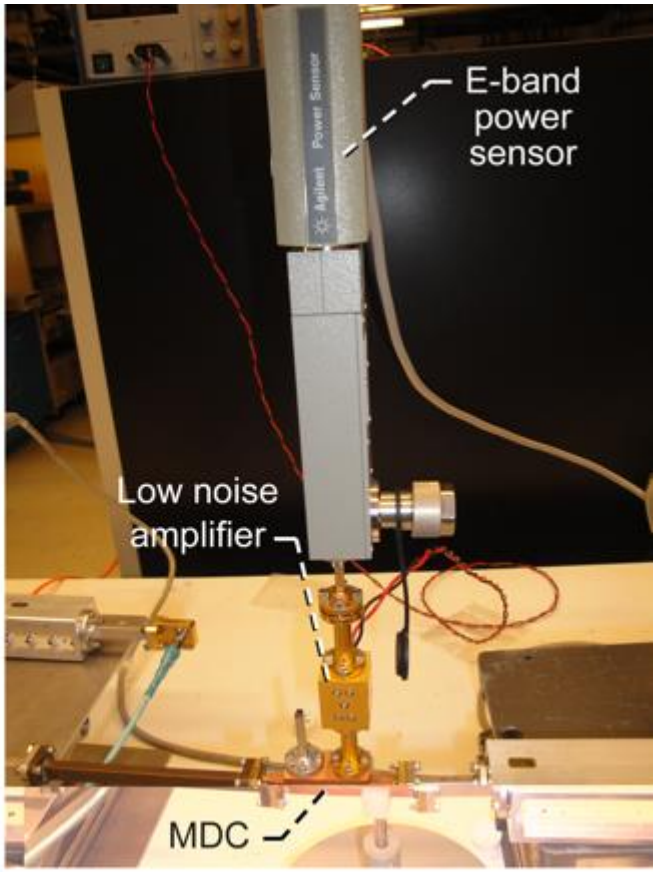


Test Circuit for Measurement of Power at Fundamental (f_0) & Second Harmonic ($2f_0$)

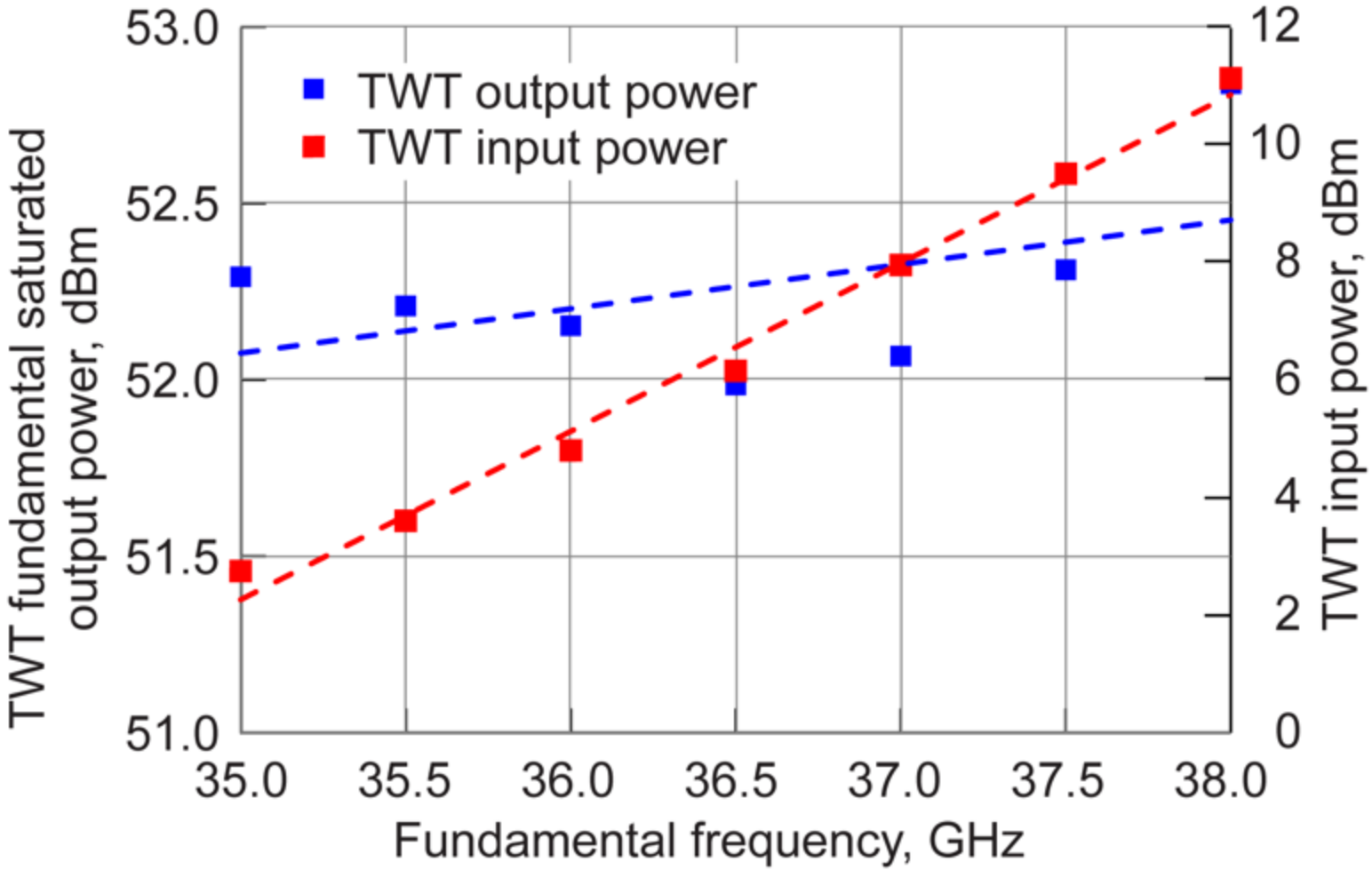


Experimental Setup - Ku-Band/Ka-Band MDC Tests

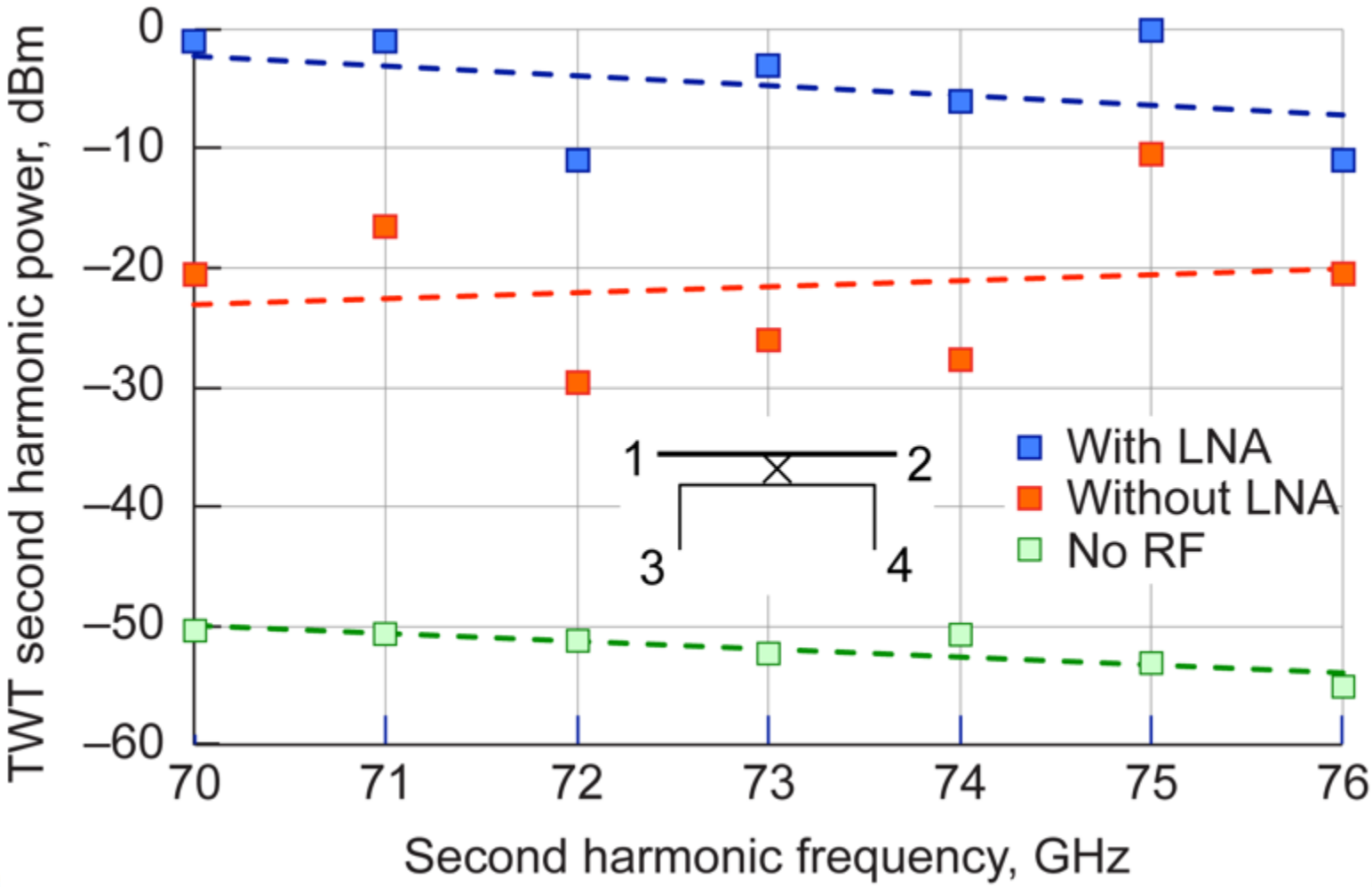




Measured TWT Fundamental (f_0) Saturated Output Power



Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC With & Without the LNA



Conclusions

- Design, fabrication and test results are presented for a Ku-Band/Ka-Band & Ka-Band/E-Band MDCs
- The MDC can be connected directly to the output port of a TWTA with negligible loss of fundamental power – an advantage over harmonic filters and diplexers
- Test results demonstrate sufficient power in the 2nd harmonic for potential space borne beacon source for atmospheric studies